A Brief History of Access Delay/Military Activated Dispensables and Their Potential for Usage as Non Lethal Weapons

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ABSTRACT

Sandia National Laboratories (SNL) has been very active in physical security systems research and development for nuclear safeguards applications addressing both fixed-site and transportation security problems. Edgewood Research and Development Engineering Center (ERDEC) has been involved for many years in the development and application of smoke obscurants, irritants, and other materials uses for battlefield applications. Many of these material technologies developed over the past 20 years as part of the nuclear safeguards and military programs have potential utility for military and law enforcement non lethal weapons (NLW) situations. This paper will provide a brief history of several activated dispensables including their development, past applications and users, and potential applications for NLW scenarios. The activated dispensables to be discussed include: rigid foam, aqueous foam, countertraction materials, and sticky foam.

Rigid Foam Materials

Rigid foam systems are under current consideration for a wide variety of Non Lethal applications. A quick setting expandable rigid adhesive can be used for field expedient equipment disablement. Second, rigid foam systems can be used to assist in securing an urban environment. One of the many jobs of the Marines, Army infantry, and MP's (Military Police) is to clear an area such as a MOUT environment (urban buildings, residences, etc.) and then move on for further missions. Once U.S. troops have left the area, the enemy is free to move back into the cleared area reestablishing their foothold. But what if our troops can quickly, easily, and safely deny an area to the enemy and make it much more difficult for the enemy to re-take the cleared area after U.S. troops have moved on. A system proposed to do exactly this is the rigid foam system. Similarly, in access delay applications, rigid foams can be used to block passage ways, encapsulate protected items, and contain deployable barriers (entanglements) which provide further delay.

Modern consideration of military use of hardened adhesive pastes can be traced back to Nazi Germany employment of *Kaltklebekilt* equipment demolition kits, accomplishing demilitarization of abandoned ordnance through hand application of a tenacious adhesive cream. By the 1960's a robust US Army effort was underway to develop a number of specialized applications of structural foam constructions for military support of counterinsurgency and remote-area conflicts (Ref. 1). In the 1980's, rigid foams were employed for a number of experimental equipment defeating concepts under the ERDEC Antimateriel Munitions Program. Finally, a novel field expedient system for land mine neutralization using rigid foams was prototyped by the US Army Demining Technology Development group at Ft. Belvoir (Ref. 2).

A number of commercial developments are worthy of note also. During the 1960's, Seamans Delivery marketed a product called, "PREVENT-A-FOAM," used for riot control purposes, to block or channel roads and sidewalks. In the 1980's the Italian-made "Instant ARMY (Anti-Robbery Mass foam-Yielding system)" family of products were marketed for installation in high security vehicles. The system provided the capability to engulf transported valuables in rapidly expanding urethane adhesive foam when necessary. This system was at one time employed by vehicles employed by the French Post Office under the acronym STOP (*Securitisation du Transport des Objets Postaux*) (Ref. 3).

Polyurethane rigid foam systems have been proposed as a material which could be applied to doors, windows, sewer covers, and other entry ways found in the urban environment thus preventing reentry through those entry ways unless destroy or damaged. The effect would be three-fold. The attacker would leave a visual clue that reentry has taken place, the attacker would make a certain amount of noise trying to gain entrance, or the attacker would give up all together, looking elsewhere for easier entrance.

The rigid foam process is based on two major chemical components - polyol and isocyanate - which are precisely metered and mixed to form the foam composition. This reaction produces an exotherm (heat generated is used to vaporize a liquid "blowing agent" such as a fluorocarbon) and may be catalyzed, allowing extremely fast cure times. Other ingredients may be added in order to produce the specific type of foam or produce the particular properties for a specific application. These ingredients include water, auxiliary blowing agents, catalysts, fillers, colorants, and surfactants. One of the most important properties of polyurethane reaction mixtures is that they are powerful adhesives. The strength of any polyurethane system is directly proportional to the final cured density. As the density of the rigid foam increases so does its strength. However other properties change also, such as expansion ratio, viscosity of starting fluids, etc., which ultimately brings challenges for dispenser designers and in how the material is mixed and applied.

Investigations have been performed by ERDEC engineers in conjunction with engineers and scientists from Southwest Research Institute (SwRI) of San Antonio, Texas, in order to investigate the applicability of using commercially-available polyurethane spray foams for use as an entry denial material, as well as the possibility for use in construction of foxhole covers. Figure 1 depicts a US Marine utilizing polyurethane foam to seal and barricade an entranceway. The results obtained using commercial, off-the shelf materials were marginal. Typically, the commercial foams consist of 2-4 pound per cubic foot (pcf) density material, which produces an expansion ratio of 15 to 1. These multi-purpose foams are generally used in the building industry for insulation, fills, and seals in and around voids and irregular surfaces. SwRI has formulated a low density 2 pcf foam with a 30 to 1 expansion ratio which can produce a foxhole cover 4ft. in diameter, approximately 1.5 inches thick with sufficient strength to support an external load of 180-220 pounds. Also, a high density 8-10 pcf foam was formulated, with a low expansion ratio, in order to produce a high strength composition capable of sealing a door or window. Also, ERDEC/SwRI have investigated several epoxies and foaming epoxies which have incredibly high compressive, tensile, and flexural strengths (Ref. 4).

Research in this area is continuing at ERDEC into the area of polyurethane/epoxy hybrids, optimization of "classic" polyurethanes by addition of strength additives (ex: Kevlar), increasing reaction kinetics through catalyst chemistry, and composites. Data will be generated on cure times, temperatures at which reaction takes place and material strength.

Aqueous Foam

High expansion aqueous foam is an aggregation of bubbles that has the appearance of soap suds and is used to isolate individuals both visually and acoustically. Aqueous foam is formed when a water and foam concentrate solution is sprayed onto a perforated screen and a continuous movement of air passes through the screen. It can be used as a visual obscurant, fire suppressant, explosive blast suppressant, and irritant carrier. Aqueous foam properties such as collapse rate and stability can also be easily tailored to specific applications.

Aqueous foam was developed in the 1920's in England to fight coal mine fires and has been widely used since for fire fighting and dust suppression. It was first used in a military application during the Vietnam War, chiefly employing CS (ortho-chlorobenzalmalononitrile) laden foams in tunnel denial operations (Refs. 5,6). Concurrently during the 1960's, aqueous foams were also considered for civil unrest scenarios (Ref. 7). Based on this developmental experience, in 1975 ERDEC (then known as Edgewood Arsenal) was requested to study the use of this technology for nuclear safeguards and security applications (Ref. 8). Additional work at ERDEC for the Defense Nuclear Agency (DNA) during the early 1980's resulted in the development of a number of antipersonnel agent laced aqueous foam formulations, some of which were patented (Refs. 9,10).

Also in the 1980's, the Department of State had SNL designed aqueous foam systems installed in several embassies for use in riot situations (Ref. 11). SNL also has developed extremely stable aqueous foam formulations for use in Nuclear Emergency Search Team (NEST) applications. In late 1994, the National Institute of Justice (NIJ), the research arm of the Department of Justice, began a project with SNL to determine the applicability of high expansion aqueous foam for correctional applications (Ref. 12). Phase one of the project resulted in the selection of a non-toxic foam concentrate (foaming agent) with physical characteristics suited for use in a single cell or large prison disturbances. The selected foam concentrate was also shown to be an excellent carrier for Oleoresin Capsicum (OC) irritant (Ref. 13). An extensive toxicology review was also performed on the selected foam concentrate to verify its low toxicity. The selected foam concentrate was then used to conduct respiration simulation experiments which resulted in measured aspirates below the threshold level for aspiration pneumonia for a one hour immersion in the foam. A prototype cell extraction aqueous foam system, depicted in Figure 2, was also built and evaluated. The prototype system was used to do large scale foam physical characteristics testing of the selected foam concentrate, and was used for evaluation by correctional representatives. The NIJ aqueous foam project is discussed in greater detail in Reference 12.

In July 1996, SNL was requested by the U.S. Marine Corps (USMC) to participate in NLW Technology Evaluations held at Camp Pendleton. SNL provided USMC with the prototype hardware developed for NIJ, aqueous foam concentrate, toxicology and safety information, and training on use of the aqueous foam equipment (Ref. 14). The USMC evaluators conducted scenario testing with the aqueous foam equipment.

Based on military and correctional testing of aqueous foam, future NLW uses of aqueous foam could include crowd control, blocking choke points, protected area access delay and area denial. Issues that have hampered the application of aqueous foams for non-lethal use have been the integration of system hardware and logistical concerns of equipment size, weight, and water supplies (Ref. 15). Although supply water will continue to be an issue, integrated, self-contained trailer-based or palletized equipment platforms modified from fire fighting hardware can be envisioned to allow rapid deployment and use in the field. Figure 3 depicts an SNL developed, application specific, integrated, self-contained, trailer-based aqueous foam platform. The depicted platform is aircraft transportable to provide rapid response and ease of deployment.

Countertraction Materials

The use of very low friction surface coatings has been suggested as a method of disabling vehicles or controlling crowd movement. In addition to roadways or sidewalks, similar targets such as aircraft runways or railroad tracks might also be targeted employing this technology. Furthermore, the application of a countertraction substance on hand operated equipment can prevent or hinder effective use due to a resultant inability to grip affected surfaces.

Modern military experimentation with this concept dates back to the US Army "Destabilizing Tactics" program, initiated during the Korean War (Ref. 16). During the 1956 Hungarian uprising against the Soviets, the insurgents were said to have been successful in hindering tank mobility by pouring oil on sloped streets to lessen traction. In attempting to hinder NVA (North Vietnamese Army) supply from the Ho Chi Min Trail in 1966-1967, slippery substances were evaluated for air delivery, to coat the roadways with water-activated materials. The US Army Tropic Test Center explored the concept in the late 1960's for riot control applications (Ref. 17). By 1981, the use of slippery material for intruder deterrence in weapons bunkers was successfully demonstrated by Edgewood Arsenal under the "Slippery Polymer Applications" program (Refs. 18,19).

Concurrent with this development, commercial ventures took root in the 1960's to employ this concept in riot control applications. The Western Company of North America marketed a product originally used to "make mud more slippery," facilitating the removal of drill bits from holes drilling for oil. Demonstrating this concept at a few of the annual National Police Equipment conventions of the mid-1960's, the product was dubbed "Riotrol." Dow Chemical marketed a similar chemical for riot control purposes called Separan AP-30. Other similar products marketed during this era were dubbed with more descriptive brand names - "Instant Banana Peel" and "Slippo." Other related commercial sector contributions include the production of artificial snow or ice surfaces to conduct winter sport activities, and applied tapes or sprays marketed as an alternative means of crawling insect control by denying them sure footing up a steeply inclined surface.

Some countertraction materials that have been considered in the implementation of this concept include specific types of polyacrylamides, carboxyvinyl polymers, or poly(ethylene oxides). Generally, these are supplied as dry white powders, and are activated by the addition of water. A second class of materials considered would include hydrocarbon-based lubricants, sometimes suggested with the addition of a dispersion of microfine fluorocarbon particles. Finally, the use of teflon or polyethylene confetti has been suggested, as the coefficient of friction of teflon on teflon is less than 0.1 (reduction of a friction coefficient much below 0.5 is generally considered to be a hazardous surface to walking personnel).

Past and current US Army countertraction technology programs have focused primarily on the water activated polymers such as the polyacrylamides. These materials should present little environmental or health hazards; many are even used in cosmetic or pharmaceutical products. As to ease of cleanup, the water-based materials have been shown to be removable through the use of high-pressure water jets. The ability of the resulting gels to sustain vertical stacking over surface smoothness imperfections is also a very important advantage in practical applications.

Effective concentration requirements for polyacrylamide based materials will vary depending on the smoothness of the surface to be treated. Studies conducted at US Army Land Warfare Laboratory recorded a requirement of 1 pound of material for 500 square feet of smooth concrete flooring (Refs. 18,19). Under the 1981 "Slippery Polymer Applications" program at Edgewood Arsenal, about 1 pound of powder was used to cover 100 square feet of rough macadam flooring (Ref. 20). Current ERDEC field trials conducted for the USMC joint NLW program have indicated that about 5 pounds of powder is required to successfully treat 100 square feet of roadway. In addition to the dry powder application, a quantity of water must also be provided to activate the material. Optimization of the weight ratio of powder to applied water is identified as an important parameter by the Edgewood project, generally taken to be about double the dry powder weight equivalent of water. Maximum effect is noticeably reduced at water applications far from the observed optimal ratio. Note that water/powder ratios are probably dependent on a number of external factors such as ambient temperature, average size of the dry polymeric particulate, degree of polymer crosslinking, etc.

These materials will not be applicable for universal usage. On paved non-porous surfaces, such as asphalt roadways or concrete runways, or on well-compacted soils these materials will produce very impressive results. However, on soft soils these materials have shown no useful effect. Heavy rain or high heat/humidity conditions will degrade the ability of this material to function effectively. One might diminish the effectiveness of this concept by simply covering the affected area with sand or dirt, or by wearing spiked shoes. Finally, for law enforcement use, the material will also adversely affect both emergency vehicles and personnel on the scene, until cleanup can be accomplished. An experiment conducted at ERDEC using a low coefficient of friction material resulted in the total immobilization of a truck as shown in Figure 4.

Sticky Foam
Sticky foam was developed at SNL in the late 1970's (Ref. 21) for use in nuclear safeguards and security applications. Sticky foam is a one-container, non-reactive foam which is stored under pressure and foams when released to atmospheric pressure. It is a very tacky and tenacious material that expands to over 30 times its stored volume when dispensed. It is comprised of rubbers, resins, oils, fire retardants and foam stabilizing chemicals. Many formulations of sticky foam have been developed for specific applications. Sticky foam also has high storage capability, contains a nonflammable solvent, is relatively volume-stable after dispensing, and requires effort and time to clean up. Sticky foam has an adherence tensile strength approximately an order of magnitude greater than common sticky materials such as molasses. Sticky foams can be deployed either passively, as in wall panel designs, or actively through nozzles, as with the sticky foam gun.

In late 1992, NIJ began a project with SNL to determine the applicability of sticky foam for law enforcement usage. The objectives of the project were to conduct an extensive toxicology and safety review of sticky foam (formulation SF-283), to develop a dispenser capable of firing sticky foam, to test the developed gun and sticky foam effectiveness on SNL volunteers acting out prison and law enforcement scenarios, and to have the gun and sticky foam further evaluated by correctional representatives. The results of the project are described in detail in Reference 22 but can be summarized as follows:

- Sticky foam is essentially non-toxic for the exposure conditions related to correctional and NLW applications.
- A capable shoulder-slung dispenser was developed and tested.

- Prison scenario effectiveness testing results were mixed: sticky foam exacerbates control and restraint problems for multiple inmates situations; however, some reduction in use of force was achieved for single inmate situations.
- Legal liability and potential suffocation concerns halted further development for prison or law enforcement applications.

In late 1994, SNL was contacted by USMC to provide non-lethal weapon support for Operation United Shield in Somalia. SNL provided USMC with several sticky foam guns, sticky foam, fill stations, emergency facial foam removal kits, training, and use protocol development. USMC performed extensive scenario testing, use-of-force protocol development, and toxicology/safety reviews prior to deployment in Somalia. Figure 5 shows USMC sticky foam gun training held at SNL. The results of the USMC sticky foam deployment are described in more detail in Reference 23, but are summarized below:

- USMC scenario testing reinforced potential applications for blocking of personnel and point access delay; however, the technology is not well suited for individual incapacitation or crowd control.
- The prototype sticky foam gun developed for correctional applications was ill-suited for military application due to limited sticky foam content, refill complexity, etc.
- Extensive reviews by both the USMC and U.S. Army (Ref. 15) have concluded that the material, deployment hardware, and safety limitations of sticky foams outweigh potential benefits. Sticky foams are no longer under consideration for further NLW research and development.

Acknowledgments

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References

1. "Army Support of Cellular Materials, Related Plastics Technology," R.J. Heaston, Army R&D News, pages 30-33, June 1966.
2. "US Army Will Try Foam to Battle Bosnia Mines," Defense News, page 11, February 24 – March 2, 1997.
3. "Instant ARMY Sticks it to the Bad Guys," Plastics News, page 6, September 10, 1990.
4. "Application of Expandable Foams to Military Objectives," Mathis, R. J. and W. A. Mallow, ERDEC Contract No. DAAL03-91-C-0034, Vol I, March 1996, Vol II, August 1997.
5. "Use of Foams in Tunnel Denial Systems," I.O. Salyer, et al., Monsanto Research Corporation, Edgewood Arsenal Contract DA-18-035-AMC-764(A), December 1966.
6. "Research on New Concepts for the Dissemination of Agents for Tunnel Denial," W.R. Grace, Edgewood Arsenal Contract DA-18-035-AMC-747(A), November 1966.
7. "Feasibility Study of a Riot Control Agent/Foam System for CONUS Riot Control Applications," C.J. Cante, et al., Edgewood Arsental Technical Report 4585.

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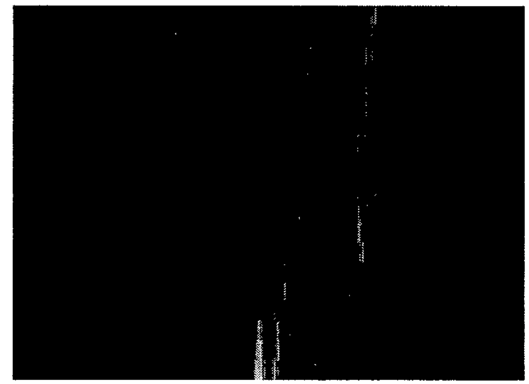
Access Delay and Military Materials Non-Lethal Applications

Sticky Foam



- Developed for access delay physical security applications - blocking, area denial, and target denial
- Characteristics
  - Exceptionally tacky/tenacious material
  - Good sustainability
  - Moderate expansion ratios (>30-to-1)
- One component, pressurized systems (100 - 225 psi)
- Extensive test & toxicology evaluation
- NIJ & USMC evaluations for non-lethal delay, blocking, personnel & equipment disablement
  - Deployed and utilized in Operation United Shield
  - No active development due to cleanup, personnel safety, operational logistics concerns

Photo of Sticky Foam Gun Testing

Photo of Airstrip Denial using Sticky Foam

Access Delay and Military Materials Non-Lethal Applications

Photo of Deployed Sticky Foam / Deployable Barriers

Department of State Aqueous Foam Application (1)

Department of State Aqueous Foam Application (2)

Wide Area Aqueous Foam Application

Integrated, Trailer-based Aqueous Foam System

Access Delay and Military Materials Non-Lethal Applications

Smart Material Development

Molecular engineering of polymeric materials / Microencapsulation

- Five potential degradation pathways
- Potential Applications
  - Reversible low-friction polymeric materials
  - Selective irritant release
  - Enhanced material strengths
  - Rate-sensitive shear thinning impact projectiles

Access Delay and Military Materials Non-Lethal Applications

Summary

- Sticky foams
  - One-component, extremely aggressive materials
  - Non-lethal issues with cleanup, operational logistics of pressurized deployment systems, personnel safety
- Aqueous Foams
  - Prior use in non-lethal delay / blocking applications
  - Potential broad applicability in non-lethal scenarios
  - Extensive support equipment required
- Countertraction
  - Limited prior uses; potential for roadway/runway denial
  - Issues of persistency
- Rigid Foam
  - Excellent for blocking, encapsulation applications
  - Significant commercial application formulation expertise

Access Delay and Military Materials Non-Lethal Applications

Future Plans

- Sticky Foams
  - No future non-lethal development planned
- Aqueous Foams
  - No current development
  - Future non-lethal applications require integrated deployment platform
- Countertraction
  - No current development
  - Chemical-based 'On/Off switch'
- Rigid Foam
  - Material optimization (all weather performance)
  - Packaging/Delivery issues

Countertraction Technology

- ***Objective:***
  -
  - Use of very low friction materials to impede access to vehicles and personnel
-
- ***Materials:***
-
  - Hydrocarbon-based lubricant
-
  - Solid polymeric ‘confetti’
-
  - Water activated polymers

Rigid Foam

- ***Objective:***
  - Area denial, quick seal of doors and windows, and misc. antimateriel applications through application of quick-set rigid foams
  -
- ***Materials:*** **Polyurethanes, epoxies**
-
  - **Tenaciously adhesive/no surface preparation**
  - **Fast cure (seconds to minutes)**
  - **Expansive (5x to 50x)**
  - **Hardens to structural rigidity**
- ***Current project at ERDEC, SNL and SwRI***
  -